[title]The Auloi from Meroë: Preliminary Notes on the Conservation, Technical Examination, and Interpretation of a Cache of Ancient Musical Instruments

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[A-head]Abstract

[abstract]

This paper summarizes preliminary results of an extensive, multidisciplinary conservation project at the Museum of Fine Arts, Boston (MFA) of a large cache of ancient musical instruments also known as “the auloi from Meroë.” The objects were discovered in 1921 during excavations by the Harvard University–Museum of Fine Arts Expedition of the burial site of Queen Amanishakheto (10 BC) in Meroë, Sudan. Multiple layers of tubing were recovered, consisting of exterior bronze sleeves encasing resonators of wood and bone. Due to the thin-walled structure of the objects, their exposure to long-term burial, and subsequent transport and handling, the pipes were fragmented virtually beyond recognition.

To date, the fragments have been documented and sorted, and many broken sections are now reconnected. Scientific examination of the materials included radio-carbon dating, identified textile fibers and wood types, and allowed insights into the complex nature of the metalwork.

Music-archaeological methods, combining the material evidence with the physics of ancient musical scales, have identified twelve individual pipes forming six pairs representing three different types of pipes, of varying length and with diverse mechanisms. The project’s long-term goal, in addition to physical reconstruction and stabilization of the ancient materials, is the fabrication of modern, functional replicas to discover the musical potential of these instruments.

**[A-head]Discovery and Introduction**

[main text]

In 1921, Harvard Egyptologist George A. Reisner excavated Pyramid N 6 (also called Beg. N. 6), the burial of Queen Amanishakheto, in Meroë, Sudan.[[1]](#endnote-1) This pyramid had been discovered in the early nineteenth century by the Italian physician and explorer Giuseppe Ferlini. While investigating the pyramid, much of which was destroyed during the process, Ferlini came upon a rich trove of gold jewelry.[[2]](#endnote-2)

A few objects however remained in the tomb, to be discovered only when excavations were undertaken in the stairway leading to the underground burial chamber. Most notable among these was a cache of wind instruments. Given the degraded state of their materials, the pipes must have been very brittle and difficult to handle. Unfortunately, little information is available about the circumstances of the find or how the objects were retrieved from the soil. The expedition diaries, allow a few glimpses into the discovery, however. The entry of March 23, 1921, reads in part: “found a number of bone tubes cased in bronze plate. These have holes and may have been a flute (or similar).”[[3]](#endnote-3) On March 24, 1921, the writer elaborates: “came on a bunch of ‘flutes’ (?) about a meter or so further on. Photo and careful notes. Appear to be made in sections (bronze casing over reed or bone tubes).”[[4]](#endnote-4) The last excavation entry of March 25, 1921, adds further information: “recording the bunch of flutes (about 18). Removed them late in the day (Sanborn and Story).”[[5]](#endnote-5) Two high-resolution excavation photographs taken in situ are invaluable today as they show the cache both when first exposed (**fig. 45.1**) and after a number of pipes had been removed.

The Object Register of the excavation of March 23–25, 1921, provides a number of drawings of the more complex and interesting sections of the instruments and the following text entry: “Many fragments of at least four (probably five) flute like musical instruments. Straight tubes of ivory encased in bronze, made in sections, with round and oblong holes, mouthpieces, stops, and fittings. Length not obtainable but cannot be less than ca. 45 cm. Jointed section preserved of L. 13.1. Appear to be large and small (cf. two end pieces of different Diameters).”[[6]](#endnote-6)

These quotes help to illuminate the confusion of the excavators when encountering this find. Up to the present day, this is by far the largest group of ancient double-reed double pipes ever found together. They clearly belong to the Mediterranean types attested all over the Hellenized world, called *auloi* in Greek and *tibiae* in Latin.[[7]](#endnote-7) The instruments consist of two separate pipes played simultaneously, each held in one hand and equipped with its own double reed. Innumerable ancient depictions of auloi are found in diverse media: in painted scenes on ceramics, in sculptures, engraved in gems, and in wall-paintings and mosaics. Early aulos finds are made from wood or bone, often with metal enforcement over the joints, but construction evolved over time; by the Hellenistic and especially the Roman Imperial periods, mechanically sophisticated systems made of various metals, bone, and wood were in use.

Although Meroë is located hundreds of miles south of the Mediterranean Sea, trade routes along the Nile and the Red Sea provided paths for cultural and commercial exchange with the north, as well as with western and central Asia. The metropolitan quality and sophistication of the city is reflected in surviving art and artifacts. That its inhabitants must also have enjoyed the increasingly globalized music culture known from the Mediterranean is further emphasized by a smaller group of aulos fragments excavated by John Garstang in the Royal City of Meroë, as well as by the standing figure of a nude aulete, carved from Nubian sandstone and covered with polychrome gesso (pink for flesh tones and yellow for the instrument), found, again by Garstang, in the “Royal Baths” of Meroë.[[8]](#endnote-8)

The first scholarly investigation of the auloi was undertaken by Nicholas Bodley in about 1939. He came to the conclusion “that a complete restoration, even of a single instrument, is not possible.”[[9]](#endnote-9) He believed the group to be the personal instruments of a professional musician, who may have participated in the funerary rites for the queen.[[10]](#endnote-10) The fragmentary instruments were subsequently revisited by Maurice Byrne in the 1990s, and in 2012 by Olga Sutkowska. By 2013, funds were raised by the MFA that allowed the beginning of the current conservation project, whose preliminary results will be discussed below.[[11]](#endnote-11)

[A-head]Conservation: Approaches and Treatment

When the project began, most of the elements were still stored in the wooden trays in which they were shipped from the Sudan in the 1920s (**fig. 45.2**). Interspersed between the fragments were small pieces of paper with notes from the excavators, some written in Arabic. We may assume that in general each tray originally contained one instrument, except for a small number of tubes that were fused by corrosion and were lifted as an agglomerate. In Boston over the following ninety years, a certain amount of undocumented handling and sorting of the various elements and materials occurred. Some bone and bronze fragments were sorted and separated into trays; in the process, many original associations were lost.

Even if the retrieval of the pipes left much to be desired, the excavators at least did not impregnate the fragments with wax or other materials favored during excavation retrieval at the time. Furthermore, prior to the beginning of the current project, no attempts at treatment had been made. We are working here with highly degraded matter, but the material is uncontaminated and unaltered by recent intervention—in other words, virgin matter.

Our initial assessment indicated that the project would access a group of elements consisting of cylindrical wooden or bone resonators, encased in thin bronze tubing, and supplemented with non-encased bone bulbs and encased reed inserts, similar to ones known from Pompeii.[[12]](#endnote-12) Furthermore there appeared to be a variety of types, not only based on their different diameters as already stated by Reisner, but also in terms of the numbers and density of finger holes, the length of sections, the shapes, and the types of mechanics (**figs. 45.3–4**).[[13]](#endnote-13)

**[A-head]Rehousing**

Further analysis, documentation, and interpretation of these fragments could only be carried out after the elements were stabilized and rehoused. The initial phase of rehousing and removal from the shipping containers was recorded in detail and was comparable to a controlled excavation, completely preserving information such as location and associated notes that may lead to further understanding of the fragments.

The wooden trays in which the fragmentary auloi had traveled the long distance from the site of Meroë in northern Sudan to Boston were recorded using high-resolution digital photography. Next, all fragments were removed from their old containers, which had permitted them to jostle against each other since their arrival in Boston almost one hundred years ago. The pieces were rehoused in state-of-the-art archival storage trays with an interior modular system of smaller boxes that allowed constant reconfiguration to serve the needs of each original particular tray. Since connections to be made between fragments during this project would lead to longer individual pipe sections, the new storage systems required the flexibility for constant adjustment. In the process, the individual pieces were cross-checked against earlier images, and their locations noted to record adjacencies that may prove to be important for future reconstruction.

**[A-head]Joining**

The interior bone resonators, bulbs, and reed holder fragments could now be handled fairly safely. Viewed against a cleaner background, many fragments now begged to be joined.[[14]](#endnote-14) The bone parts, especially, exhibit specific shapes, textures, and sometimes incised surface decorations, all of which greatly helped to identify joins. The green stain observed on many parts and of varying hues was caused by contact with copper tubes in burial, and not by an original dye, as previous researchers had assumed. Many of the bulbs carried decorative silver sleeves, now mineralized to a brown, warty appearance.

The outer bronze sleeves and tubes were far more difficult to join. The thin walls of the heavily corroded, and sometimes also mineralized, metal have occasionally warped, complicating the reconstruction of the original forms. The thin-walled copper alloy tubes, however, also show distinctive patterns, related to the taphonomic micro-conditions that surrounded them. These features occasionally allow identification of pieces that belong to one tube, but may more often help corroborating hypotheses built on different grounds. Many pipes consisted of numerous short bronze tubes, joined with socket-and-tenon joins of the inner bone lining. In cases where the bone lining was separated from the metal tubes, joining of tube sections based on the material evidence alone was almost impossible.

The wood is so fragile that for the time being any manipulation of it is avoided.

[A-head]Material Analysis

*X-radiography:* To date, all metal elements have been examined by X-radiography (**fig. 45.5**). The radiographs provide insight into the highly sophisticated fine mechanics of the auloi: uniform sections of extremely thin and straight bronze tubing (some less than 0.3 mm thick) were fitted into each other to form an airtight system. As with other aulos finds, wall thickness is basically homogenous and none of the straight tube sections show seams, with the single exception of a long piece of tubing without any mechanism.[[15]](#endnote-15) The generally mottled appearance of the tubes is due to corrosion, which led to uneven loss of metallic substance. One particularly interesting feature seen first in the radiographs as dark lines, are straight slits or cuts on many short tubes, where thin partial rings were intentionally cut from the tube’s end. These presumably mechanical features are so far unique to the Meroë double pipes and although we have developed hypotheses about their function,[[16]](#endnote-16) these remain to be verified by experimental reconstruction.

*Alloy Analysis:* Surface analysis by energy-dispersive X-ray fluorescence, a nondestructive analytical technique, provided initial semi-quantitative information on the elemental composition of various elements of the instruments: of straight tubes, knobs, and metal encasing on the bone bulbs. It appears that large sections of the round tubes were made from a copper-tin bronze. Lead was detected in areas that were once joined by soldering, and silver was found on various bone bulbs.

*Cross Section:* A polished and etched metal cross-section of one narrow tube revealed a highly stressed metal structure that was cold worked and annealed during manufacture. Based on this observation, it is assumed that the seamless tubes were cast from tin bronze and then likely further hammered, possible around a metal core. Final turning and smoothing of the surface with a lathe-like instrument facilitated the perfect fitting of extremely thin, straight tubes, leaving distinctive parallel marks on the metal surface (**fig. 45.6**); these can be seen in a few locations on the bronze tubes that have not been mineralized by corrosion. Quantitative elemental analysis on the cross section determined that they were made of tin bronze with about 90% copper and 10% tin.[[17]](#endnote-17)

#### *Carbon 14 Dating:* Samples from wooden core material were dated by radiocarbon analysis to between 52 BC and AD 54, congruous with the burial of Queen Amanishakheto. Her instruments were au courant![[18]](#endnote-18)

Wood Identification: Analysis was carried out by Caroline Cartwright of the British Museum on five wood samples from different original storage boxes, some of them associated directly with specific bronze tubing. She identified the wood as that of Olea europaea, the European olive, which is not native to the Sudan. This suggests that the double pipes were manufactured far north of Meroë utilizing wood from the Mediterranean sphere.[[19]](#endnote-19)

*Bone:* Based upon initial visual examination, the lining of many pipes, as well as their bulbs and bells, appear to have been primarily carved from bone; as mentioned above, these parts are sometimes light green in color. Different parts of the pipes appear to have been carved from different types of bone, judging by their surface textures. Such slight variances and the occasional surface decoration in the form of thin incised lines aid in establishing joins between the numerous small fragments.

Fiber Analysis: Textile fibers were found on both the rotating sleeves of the instruments and the knobs by aid of which these were operated. Some of the fibers appear to wrap repeatedly around the rotating sleeve or knobs, while others are inserted into the holes of knobs (**fig. 45.7**). The exact use of the fibers is not known, but it was postulated that the yarns might assist in the rotation of the sleeves in some way (perhaps by giving the player a way to turn the sleeves by pulling the yarns), or cushion the sharp top edge of the knob with wrapped fibers to make playing more comfortable. Alternatively, the yarn may have simply been used as decoration. Preliminary analysis by Joel Thompson, Associate Conservator in Textile Conservation at the MFA, has identified the fibers as extremely fine flax, although much more detailed studies are required to map the location of all fibers associated with the instruments.

**[A-head]Music-archaeological Interpretation**

In late spring 2015, a group of music archaeologists, leading researchers of ancient music and in particular of auloi—Stefan Hagel of the Austrian Academy of Sciences, Peter Holmes of Middlesex University London, and Olga Sutkowska of the Universität der Künste Berlin—joined the project.[[20]](#endnote-20) The expertise of the music archaeologists and their previous detailed studies of auloi in European collections have been indispensable.[[21]](#endnote-21) The goal for their work was twofold: to assemble as many complete or near-complete instruments as possible, and to prepare detailed documentation that will hopefully lead to the production of playable replicas.

After sorting tube sections by internal and external diameters and other distinctive features, tentative arrangements of the first double pipes were made. For a couple of sections, the two abovementioned photographs taken of the fragments in situ were helpful, and corrosion patterns on the outer bronze tubes were taken into account throughout. Most of the material, however, found its likely place only with the help of a grid of relative finger-hole distances for the various notes of the ancient musical system, in combination with information on how these may have worked together, both from the remnants of ancient scores and from theoretical treatises. In addition, it needed to be assessed whether any proposed arrangement of finger holes could possibly be played by the human hand—taking into account the highly trained hands of ancient professional players with considerable finger spans evidenced from other aulos finds. As a first result, by June 2015, hypothetical layouts of eight pipes forming four instruments had been created, with at least four more pipes and additional tubing sections remaining to be studied.

Stefan Hagel returned in the fall of 2015 for a second study session and now six instruments are tentatively identified, consisting of twelve pipes and accounting for nearly all of the section fragments. Each double pipe is distinguished by different features, including length and mechanisms.

The reconstruction of the two longest pairs—longer than any other ever found—was greatly helped by the fact that these instruments were musically very similar, differing only in the musical capabilities of their bass regions, far below the playing position of the hands. Their four tubes were also equipped with identical slider mechanisms that end in small dolphin sculptures, each one holding a seashell in its snout (see fig. 45.4). These shells would have covered sound holes and could be pushed up and down along the tubes to switch between two different bass notes.

After the reconstruction of these four pipes had reduced the pool of fragments by twelve feet worth of tubing, the remaining eight pipes belonging to shorter instruments became easier to tackle. Four of these belonged to a previously unknown type of aulos without a bulb, terminating at their upper ends in a reed insert whose flare is nearly reciprocated at the lower ends. These came mostly with a wooden core and with hardly any rotating sleeves, forming the simplest instruments in the cache.

In contrast, the remaining two pairs had rotating sleeves throughout, resulting in relatively high-pitched and highly chromatic modulating instruments. Their reconstruction was encumbered by the sheer number of very small sections, where the short distances between the finger holes sometimes required compromises on the part of the makers, sacrificing exact intonation for the sake of fingering. However, in the end it proved possible to arrive at a musically meaningful interpretation of this group as well, which currently awaits corroboration first by physical modeling and then by experimental reconstruction. The former is done with specialized software that allows the assessment of pitches and scales of such instruments based on their physical parameters, establishing the optimal measurements of the lost reed mouthpieces as well as the likely placement of lost holes, in the very few cases where this may be required.[[22]](#endnote-22)

Numerous smaller stray bronze elements, mostly broken away from the external layers of existing sections, still must be considered. These have now been sorted, rather like a jigsaw puzzle, into groups with specific edges, such as end sections of tubes, pieces with remnants of sound holes, small ring sections, and the like.

**[A-head]Concluding Remarks**

Future study sessions with the team members within the next year are anticipated. With the completion of reasonably accurate copies, the musical potential of such instruments could be rediscovered, adding immeasurably to our knowledge of music in the Roman period. A first trial by Stefan Hagel playing 3D-printed replicas of the “Wooden Pipes” took place in January 2016 in Paris during a conference focused on the making of ancient musical instruments, in part organized by the [Institut français d’archéologie orientale](http://www.ifao.egnet.net/) (IFAO).[[23]](#endnote-23)

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1. Excavation numbers 21-3-350, 21-3-702. Dunham 1957, 109, plate LIX A, B. [↑](#endnote-ref-1)
2. Priese 1993, 12–15. Today, the preserved gold jewelry is primarily divided between the collections of the Staatliche Sammlung Ägyptischer Kunst München and the Ägyptisches Museum und Papyrussammlung, Staatliche Museen zu Berlin – Preussischer Kulturbestitz. [↑](#endnote-ref-2)
3. Harvard University–Museum of Fine Arts, 1920–21a, 253. See also West 1992, 81–107. It is worthwhile to point out that the term “flutes” used by Reisner (and others) in connection with the Meroë auloi is incorrect. The instruments are predominantly referred to as “double pipes” in this article, each formed by two “pipes.” [↑](#endnote-ref-3)
4. Harvard University-Museum of Fine Arts, 1920–21a, 255. [↑](#endnote-ref-4)
5. Harvard University-Museum of Fine Arts 1920–21a, 256. [↑](#endnote-ref-5)
6. Harvard University-Museum of Fine Arts 1920–21b, 302. Thanks are due to Denise Doxey for helping to read the handwriting in this register. [↑](#endnote-ref-6)
7. West 1992, 81–107. [↑](#endnote-ref-7)
8. Southgate 1915. The object was mounted and photographed by the Liverpool Institute of Archaeology. The short sections visible in the published image appear to show close similarities to some of the sections from Meroë. See Dixon and Wachsmann 1964 for a discussion of the aulete from Meroë, now in the Petrie Museum, London (inv. UC 8964). [↑](#endnote-ref-8)
9. Bodley 1946, 218. [↑](#endnote-ref-9)
10. Bodley 1946, 217. [↑](#endnote-ref-10)
11. This project is funded by generous donations from members of the Visiting Committees of the Departments of Musical Instruments, Art of the Ancient World, and Conservation and Collections Management, Museum of Fine Arts, Boston. <http://www.mfa.org/collections/conservation/feature_auloiofmeroe> [↑](#endnote-ref-11)
12. Hagel 2012a. [↑](#endnote-ref-12)
13. Most recently the instruments were included in an MFA Highlights book on musical instruments, see Kuronen 2004, 61. It should be noted that prior to the collaboration with the music archaeologists in 2015, small bone cones have been repeatedly misinterpreted as bells, i.e., bottoms of flutes, also by Bodley (1946, 235). See also Byrne 2002. [↑](#endnote-ref-13)
14. The adhesive used in the treatment is Rohm+Haas Paraloid B 72 (a conservation grade ethyl-methacrylate copolymer). It can be prepared in a variety of concentrations in a number of solvents, remains reversible, and does not darken or prevent future treatment or reversal of joins. [↑](#endnote-ref-14)
15. In contrast, solder seams were found on a Gallo-Roman trumpet by Mille, 2007. [↑](#endnote-ref-15)
16. Sutkowska 2015, 412–22. [↑](#endnote-ref-16)
17. Byrne (2000) quotes the alloy of the C2AD aulos from London as 91% copper and 9% tin. [↑](#endnote-ref-17)
18. Christine Prior, Rafter Radiocarbon Laboratory, National Isotope Centre, GNS Science  
    30 Gracefield Road, Lower Hutt, New Zealand. [↑](#endnote-ref-18)
19. See also Cartwright 2015. [↑](#endnote-ref-19)
20. All of them take part in the European Music Archaeology Project (EMAP), which has among other things allowed the reconstruction of one of the Pompeii double pipes as well as the investigation of the fragments from Poetovio. Their work to date has laid the foundations critically required for the interpretation of the Meroë pipes. [↑](#endnote-ref-20)
21. Hagel 2008, 2009, 2012a, 2012b; Sutkowska 2012, Sutkowska 2015. [↑](#endnote-ref-21)
22. Hagel 2004; 2014. [↑](#endnote-ref-22)
23. *Sound Making: Handcraft of Musical Instruments in Antiquity*: IFAO, Paris, January 14–16, 2016. [↑](#endnote-ref-23)